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PERCEPTION OF MILITARY EVENT PATTERNS IN A TWO-ALTERNATIVE PREDICTION TASK

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SUPPORT SYSTEMS RESEARCH DIVISION

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PERCEPTION OF MILITARY EVENT PATTERNS IN A TWO-ALTERNATIVE PREDICTION TASK

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FOREWORD

Technological advancements have led to increased speed, mobility, and destructive power of military operations. To permit commanders to make tactical decisions consistent with rapid change and succession of events, information on military operations must be processed and used more effectively than ever before. To meet this need, the Army is developing automated systems for receipt, processing, storage, retrieval, and display of different types and vast amounts of military data. There is a concomitant requirement for research to determine how human abilities can be utilized to enable the command information processing systems to function with maximum effectiveness.

BESRL's Command Systems Research Program embraces two major work units, one dealing with tactical information processing, the other with tactical operations systems. The entire research effort is responsive to requirements of RDT and E Project 2Q024701A723, "Human Performance in Military Systems," FY 1970 Work Program, as well as to special requirements of the Assistant Chief of Staff for Force Development, the Assistant Chief of Staff for Intelligence, and the U. S. Army Computer Systems Command.

One objective of the TACTICAL OPERATIONS SYSTEMS (TOS) Work Unit is to provide research information by which decision making and information assimilation from displays may be facilitated. The present study dealt with certain aspects of perception fundamental to the recognition of sequence patterns of military activities. The objective was to develop empirical data useful in efforts to improve the recognition of such patterns and the anticipation of enemy moves.

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PERCEPTION OF MILITARY EVENT PATTERNS IN A TWO-ALTERNATIVE PREDICTION TASK

BRIEF

Requirement

In order to improve the timely recognition of cues to enemy action, research must be conducted to determine how recognition of patterns of military events is affected by the form (sequence of events), strength (probability of occurrence) and continuity of event pattern, and by the amount of experience the individual has had with the particular pattern.

Procedure:

Sequences of events representing eight patterns (form), high and low pattern strength, continuous vs discrete occurrence, and experience from one to ten 100-trial periods were presented on a CRT screen in systematic design to 48 enlisted men. The enlisted men indicated which of two enemy activities (attack or rest) was likely to follow each two-event clue. Results in the form of prediction of the most frequently occurring third event in a sequence and confidence (high or low) expressed in the decision were subjected to analysis of variance.

Findings:

Given a pattern of events occurring with sufficient frequency (80% of the time) and sufficient experience with the patterns on the part of the decision maker, the men learned to predict the third event in a sequence as often as it occurred. However, when the pattern occurred less frequently (68% of the time), the men recognized only one of four critical patterns.

Subjects' confidence in their predictions increased as their experience with the task increased. Confidence was affected by pattern form~~ in that subjects' confidence in their predictions for one of the eight forms (rest, rest, attack) was significantly less than for the others~~. Confidence was not affected by pattern strength nor continuity.

Application of Findings:

Activity patterns of an enemy may be the most tangible cues to his plans, and recognition of these patterns may be critical to successful military operations. The present experiment has set tentative limits on the event patterns men can learn to recognize to a useful extent. A computer may be a useful aid in detecting weak but significant patterns in an apparently random set of enemy actions.

PERCEPTION OF MILITARY EVENT PATTERNS IN A TWO-ALTERNATIVE PREDICTION TASK

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PERCEPTION OF MILITARY EVENT PATTERNS IN A TWO-ALTERNATIVE PREDICTION TASK

Future automated data processing systems promise improved accuracy, completeness, and speed of information processing. These systems may also be capable of limited data evaluation for decision making. Such a system has been proposed by Edwards (1). In the automated system, each new item of information is evaluated and entered into a probabilistic information processing system which updates the current diagnosis on the basis of the new information. Since system inputs originate from many men, sources, and locations, each item is likely to be evaluated independently as it enters the system. Frequently, however, the interrelationships of items of information may add diagnostic value beyond that obtained by separate and successive evaluations of individual items. For example, consider two items, an intelligence report of a massive increase in the number of enemy troops participating in military exercises, and domestic news of the assassination of a president.

Each of these events may have one meaning if they occur separately. Their joint occurrence may be a strong indicator of enemy aggression. Since the two events have been reported from different sources, they may be evaluated separately by an automated information processing system. The commander, however, may well interpret the joint occurrence of these events as a pattern leading toward aggression. He may "perceive" a threat and conclude that the enemy is about to attack.

Needless to say, this ability requires experience in observing the activities of the particular enemy under consideration. As a commander or decision maker gains this experience, he renders more accurate judgments concerning present and future enemy activities. In a more analytical manner of speaking, he is learning which aspects of the enemy's activities are relevant cues in predicting future enemy events and which are not. By learning which cues are associated with which outcomes, the commander is learning the enemy activity patterns.

A well-known probability learning paradigm, which has served as a useful vehicle for investigating many facets of human learning, requires the subject to predict in a series of trials which of two lights will come on. While his first prediction can be little more than a guess, succeeding choices can benefit from knowledge acquired through observation of earlier outcomes. Thus, his second prediction is made in light of what happened on the first, his third in light of the first two, and so on. The second and subsequent predictions, then, may reflect his perception of one or more cues which are present within the experimental environment. A cue may be defined as any stimulus or set of stimuli which is correlated with the occurrence of an event (e.g., one of the lights). Thus, any cue affords the subject the opportunity to improve his prediction accuracy.

The present investigation concerns the learning of event structure, that is, the orderly occurrence of events within the environment, and the cues the structure affords. A *marginal* cue is an event in a series of events which occurs more frequently than any other event in that series. A *first-order* cue is an event whose occurrence signals what the next event will be. For example, the sight of a lightning flash is a cue which signals the sound of thunder. A *second-order* cue is a pair of events whose occurrence signals the event which is to follow. In baseball, if the first *two* pitches to a batter are strikes, the next pitch is usually a ball.

Of course, the cues observed in nature and man are not always reliable. The sound of thunder from distant lightning flashes is not always heard. A ball does not always follow two strikes. However, as long as sound follows lightning more often than silence follows, and as long as a ball follows two strikes more often than a third strike, the cues are valid.

Previous probability learning experiments have investigated man's ability to respond to various classes of cues (marginal, first-order, second-order) of varying strength. The results of these studies show that subjects are capable of learning marginal cues, as evidenced by the fact that their response frequencies generally match the relative frequency of the respective events over trials. For a review, see Luce and Suppes (2). Subjects also match or exceed matching (overshoot) events signaled by first-order cues (3) (4) (5) (6). There has been little research concerning second-order cue learning and the findings are not straightforward. Data from Bennett, Fitts, and Noble (7) suggest that in a five-event environment (the occurrence of one of five lights), subjects are unable to learn second-order cues. In a two-event environment (the occurrence of a left or right light, L or R), Strub and Erickson (8) found that subjects did learn certain highly structured second-order cues. Subjects tended to match their response frequencies to all second-order events when conditional probability was set at .92 (a value indicating the probability of the occurrence of an event, given the occurrence of the two preceding events). When it was set at only .72, however, subjects seemed to take the specific form of each second-order event pattern into account. The four more frequent patterns were obtained by combining all possible second-order cues (L-R pairs) with an L or R third event as follows: LLL, RLR, LRR, and RRL. At the .72 level, subjects overshot LLL, matched RLR and LRR, but did not learn RRL at all.

In a frontless war such as that being fought in Vietnam, the activity patterns of a local enemy may be the most important clues to his position and intention. Therefore, the timely recognition of these patterns can be critical to successful military operations.

OBJECTIVES OF THE PRESENT STUDY

Since very little is known concerning military pattern perception, research at a relatively basic level is needed to answer some fundamental questions. The present study addressed itself to the following questions: First, does the form of the pattern affect the subject's perception of it? For example, if an enemy pursues a course of repeated attacks after resting two days (where each day's activity, rest or attack, constitutes an event), a second-order pattern of the form rest-rest-attack would be exhibited. Is this form any more or less difficult to recognize than other forms such as attack-attack-attack, attack-rest-rest, or rest-attack-rest? A second question concerned the range of pattern strength within which patterns are recognized. Assuming subjects can recognize second-order patterns of 92% strength (8), can they also recognize them at 80%, are any patterns recognizable at 68%? Third, does continuity affect second-order pattern learning? Is it more difficult to discover second-order patterns in a continuous flow of events than in discrete second-order pattern units? Fourth, to what extent does experience, the repeated exposure to the patterns, enable the subject to perceive the relevant second-order patterns? Finally, does the answer to any one of the above questions depend on the answer to another, that is, are there significant interactions among the independent variables under investigation in the present study?

In summary, the objectives of the present study were as follows:

1. To determine the effect of different forms of second-order patterns on pattern recognition.

2. To determine the effect of second-order pattern strength on second-order pattern recognition.

3. To determine if continuity affects second-order pattern recognition.

4. To determine the effect of experience, i.e., the extent to which second-order pattern learning occurs over periods within the experiment.

5. To assess any interactions among two or more of the above variables (form, strength, continuity, and experience).

METHOD

Subjects

Forty-eight enlisted men from Ft. Belvoir, Virginia served as subjects. All had GT scores of 110 or above. Many had served one year in Vietnam. Average length of service was estimated to be 13 months.

Apparatus and Stimuli

Six cathode ray tubes (CRT's) were used in the present study. Each CRT consisted of a vertically mounted television-like screen on which stimulus material was displayed and a horizontally mounted typewriter keyboard at the base of the screen on which the subject typed his responses. Each CRT screen was positioned at eye level. The CRT was linked to a computer which was programmed to generate separate event schedules for each subject prior to each session and to coordinate the simultaneous use by six subjects.

Event sequences were prepared as follows. The computer selected events without replacement from a 100-event population in order to insure that the exact probability specifications were realized after every 100 events. The specific order of the stimulus events for each subject was determined randomly at the start of each experimental session. Thus, while event sequences for subjects in each group contained the same conditional probabilities, the exact ordering of events from alternative to alternative was different for each subject.

Procedure

Six subjects worked individually during each experimental session. Prior to the first session, they were briefed concerning the general nature of the experiment (decision making). They were also told not to discuss the experiment among themselves until its conclusion. Each man was then assigned a CRT and each received the following instructions on his screen:

> This is an experiment in basic military decision making. Your task will be to decide which of two activities will occur, that is, to predict whether enemy X is going to (1) attack or (2) rest. You indicate your decision by pressing a 1 or 2 on your keyboard and then pressing the "send" button. Next you will indicate your confidence by pressing and "sending" 1 if you think you have better than a 50-50 chance of being correct, or 2 if your decision was, quite frankly, a guess. Next, you will be informed as to which of the two activities did, in fact, occur. The next push of the "send" button will start a new decision situation. Follow this same procedure for the second and subsequent decisions.

Each subject served in two experimental sessions, morning and afternoon. Each session consisted of five 100-choice periods with a 10-minute break between periods, mainly to relieve eye strain produced by the continuous viewing of the display. Each subject worked at his own pace and kept track of his own break time. The morning session extended from approximately 0800 to 1030, the afternoon session from 1300 to 1500. At the conclusion of the experiment, subjects were debriefed concerning the purpose of the experiment in which they had participated.

Independent Variables

<u>Form</u>. The first independent variable was the form of the second-order pattern. Table 1 illustrates the eight possible second-order pattern forms. Event sequences were constructed such that the forms AAA, RAR, ARR, and RRA occurred more frequently than AAR, RAA, ARA, and RRR (A = attack; R = rest).

<u>Strength</u>. The second independent variable was the strength (frequency of occurrence) of the second-order pattern. Two strengths were employed, .68 and .80. These percentages represent the second-order conditional probability of occurrence of the second-order patterns. [Under high strength, given that the last two events were A, a third A would follow 20 of 25 times (80%), while R would follow 5 of 25 times (20%). Thus, the second-order conditional probability of AAA and AAR was .80 and .20, respectively.] Table 1 indicates the structure of the second-order patterns in terms of both frequency of occurrence and conditional probability for high and low strength.

Table 1

FREQUENCY AND CONDITIONAL PROBABILITY STRUCTURE FOR EACH 100-TRIAL EVENT SEQUENCE

Form			Frequency		Conditional Probability	
2-Days Ago	Yesterday	Today	Strength High	Strength Low	Strength High	Strength Low
A(ttack)	A	A	20	17	.80	.68
A	A	R(est)	5	8		
R	A	R	20	17	.80	.68
R	A	A	5	8		
A	R	R	20	17	.80	.68
A	R	A	5	8		
R	R	A	20	17	.80	.68
R	R	R	5	8		
			100	100		

Continuity. The third independent variable was the amount of day-to-day continuity. For the continuous case, events occurred consecutively over 100 days; thus, the event which was displayed as having occurred yesterday was the correct event on the preceding trial. In the discrete case, reports of the previous day's activities did not follow a temporal order beyond three days; the subject was simply shown the reports for the past two days and requested to choose the next event. A fresh set of reports for the past two days was then presented.

Experience. The fourth independent variable was experience, which consisted of ten 100-trial periods.

Dependent Variables

1. Prediction--The proportion of times the subject chose the more frequently occurring patterns. If a and r are choices, the choice score equals AAa + RAr + ARr + RRa/100.

2. Confidence--The proportion of times the subject indicated high as opposed to low confidence. If "h" is high confidence, the confidence score equals AAh + RAh + ARh + RRh/100.

Design

Table 2 illustrates the experimental design. Pattern strength and pattern continuity, the two variables administered at two levels, were between-subject variables with 12 subjects within each of the four resulting experimental groups. Pattern form and experience were within-subject variables, each subject receiving all four pattern types and serving in all ten periods.

RESULTS

Prediction Data

An analysis of variance on the prediction data was performed and a summary of that analysis appears in Table 3. While significant main effects of form, strength, continuity, and experience provide information relevant to the first four objectives of the study, the implications of each of these effects are limited because each interacted significantly with at least one other effect. Thus, the fifth objective of assessing interactions among the variables must be considered important in view of the significant interactions in the analysis shown in Table 3.

Table 2

EXPERIMENTAL DESIGN

			Experience										
			Period I Trials 1-100				.	.	.	Period X Trials 901-1000			
	Form		AAA	RAR	ARR	RRA	.	.	.	AAA	RAR	ARR	RRA
High Strength (80%)	Continuous	S 1		Sequence	1		.	.	.		Sequence	10	
		.		.	11		.	.	.		.	20	
		.		.			.	.	.		.		
		.		.			.	.	.		.		
		S 12			111		.	.	.			120	
	Discrete	S 13		Sequence	121		.	.	.		Sequence	130	
		.		.	131		.	.	.		.	140	
		.		.			.	.	.		.		
		.		.			.	.	.		.		
		S 24			231		.	.	.			240	
Low Strength (60%)	Continuous	S 25		Sequence	241		.	.	.		Sequence	250	
		.		.	251		.	.	.		.	260	
		.		.			.	.	.		.		
		.		.			.	.	.		.		
		S 36			351		.	.	.			360	
	Discrete	S 37		Sequence	361		.	.	.		Sequence	370	
		.		.	371		.	.	.		.	380	
		.		.			.	.	.		.		
		.		.			.	.	.		.		
		S 48			471		.	.	.			480	

Table 3

ANALYSIS OF VARIANCE SUMMARY TABLE ON PREDICTION DATA

Source	df	MS	F	p
Between Subjects	(47)			
Strength (S)	1	8044.218	34.13	.001
Continuity (C)	1	946.408	4.02	.05
S x C	1	470.052	1.99	
Ssw/SC	44	235.672		
Within Subjects	(1872)			
Form (F)	3	3008.420	10.03	.001
F x S	3	558.650	1.86	
F x C	3	1313.612	4.38	.01
F x S x C	3	725.850	2.42	.10
F x Ssw/SC	132	300.086		
Experience (E)	9	186.206	12.79	.001
E x S	9	92.357	6.34	.001
E x C	9	6.033		
E x S x C	9	23.711	1.63	.10
E x Ssw/SC	396	14.559		
F x E	27	42.137	3.04	.001
F x E x S	27	20.545	1.48	.10
F x E x C	27	13.592		
F x E x S x C	27	15.491	1.12	
F x E x Ssw/SC	1188	13.858		

To facilitate interpretation of the experience x strength interaction ($p < .001$), mean prediction scores for all pattern forms across periods were plotted as a function of pattern strength (Figure 1). The high strength proportions reflect a slow but steady increase across periods and rise to a level where prediction of the stronger patterns are matching their proportion of occurrence (.80). The low strength patterns, on the other hand, exhibit little indication of second-order recognition, implying that the patterns are unlearnable when the conditional probability of their occurrence is set at .68 or below. This implication must be tempered, however by the form x experience interaction ($p < .001$) shown in Table 3. Interpretation of this effect may be made by inspection of Figure 2. It is apparent from Figure 2 that all groups achieved a level of mastery of the attack-attack-attack pattern that was not reached for any other pattern. In addition, this level for AAA was attained after 800 trials, after which performance leveled off.

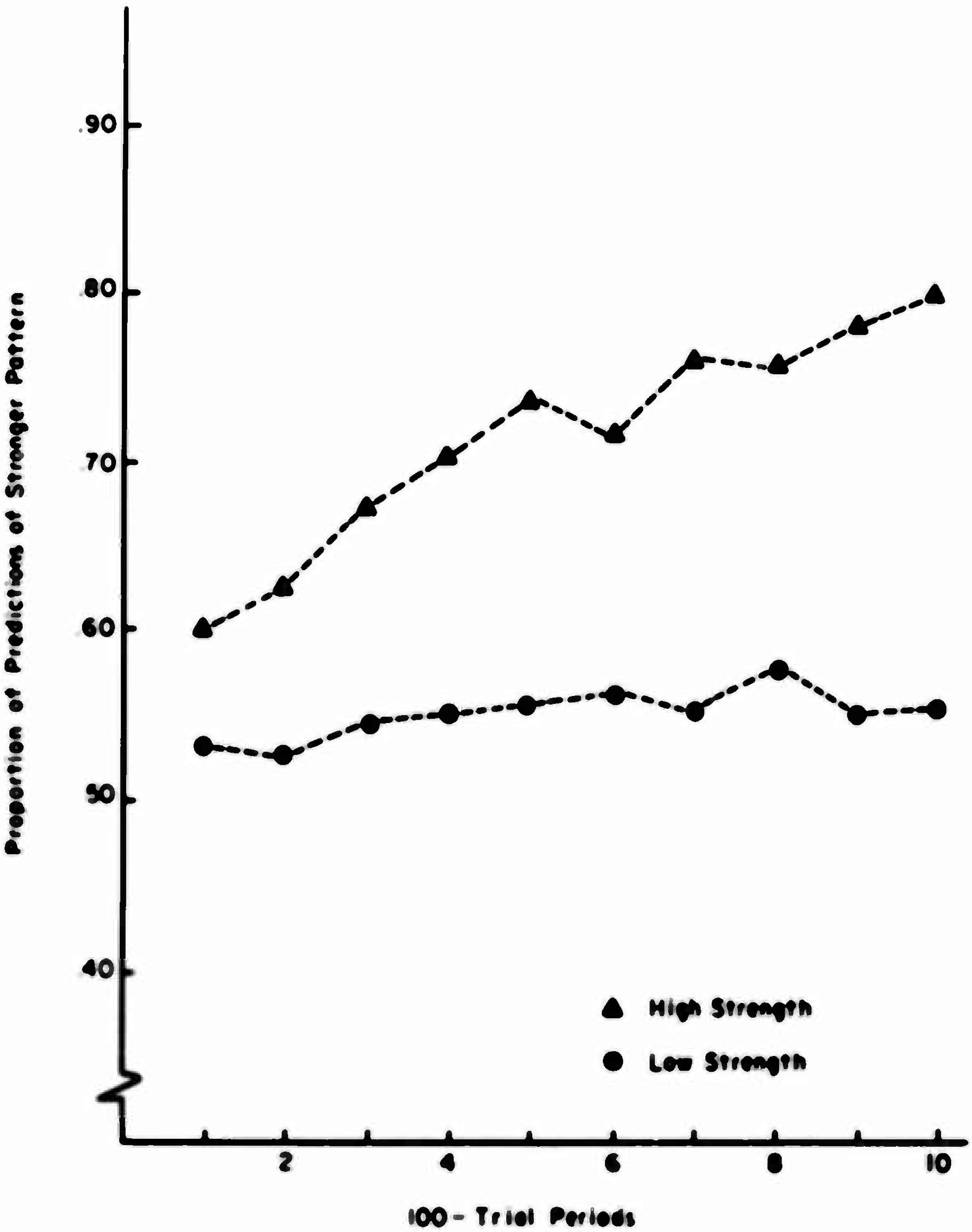

Figure 1. Predictions of stronger patterns across periods as a function of pattern strength

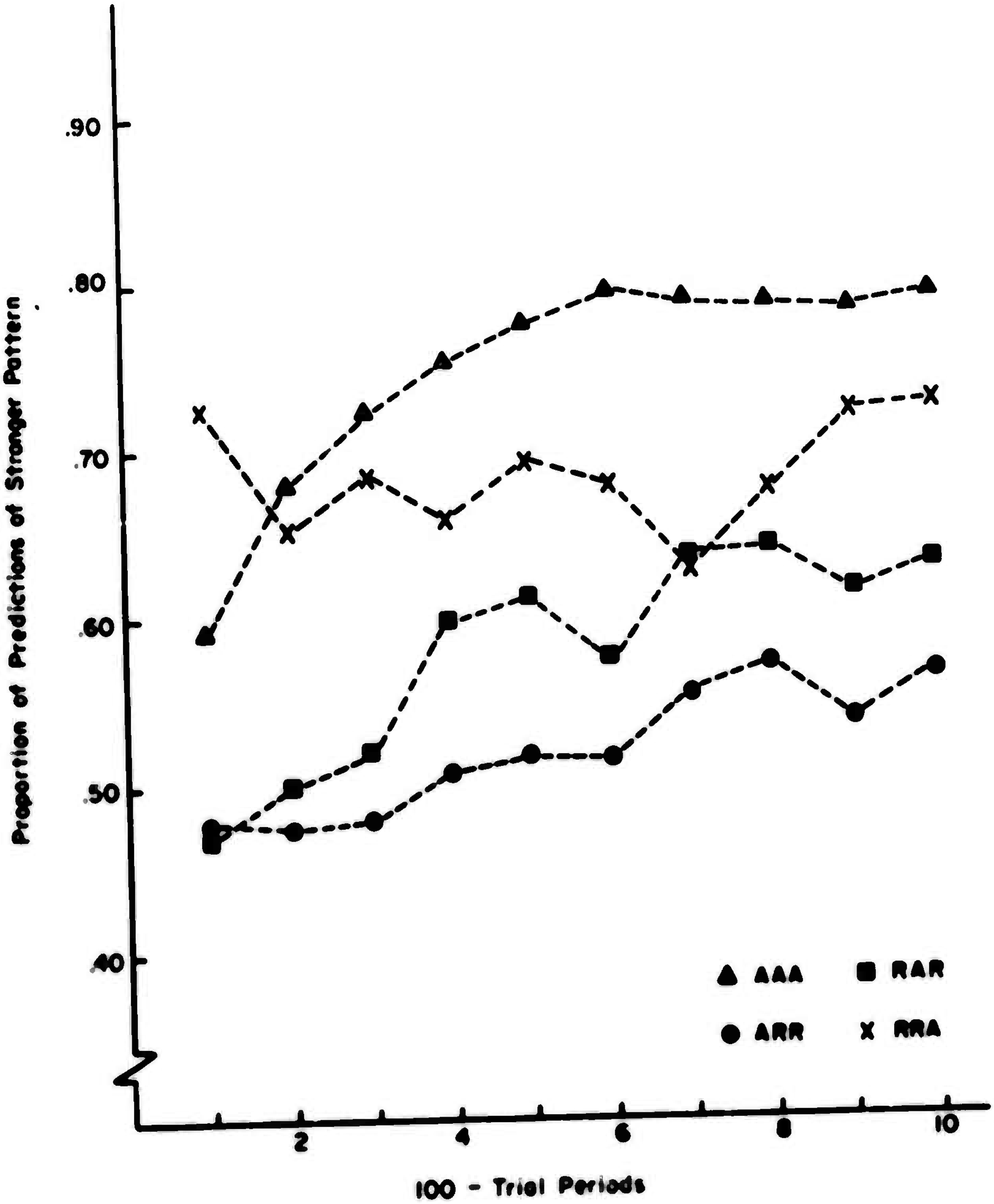

Figure 2. Proportion of predictions of stronger second-order patterns across periods

The form x continuity interaction of Table 3 ($p < .01$) is plotted in Figure 3. Note that the means for groups presented the continuous sequences were above those of the other groups for all patterns except rest-rest-attack whose prediction was less frequent in the continuous groups. A further isolation of the rest-rest-attack pattern is shown in Figure 4 which traces the patterns across levels of continuity as a function of pattern strength. Here, it is apparent that the decrement in predicting the rest-rest-attack pattern occurred only at low strength, although the form x strength x continuity interaction was not significant ($p < .08$).

In summary, while form, strength, continuity, and experience all had significant effects on the proportion of predictions of the stronger pattern, each of these effects was involved in one or more interactions. The form x experience interaction is interpreted as a tendency for attack-attack-attack to be recognized better than any other pattern across the ten 100-trial periods of the experiment. The strength x experience interaction is interpreted as a tendency for all patterns to be better learned in the high than in the low strength conditions across periods. Finally, the continuity x form interaction is interpreted as due to the tendency for three of the four second-order patterns to be better recognized in the continuous than in the discrete sequence, while the fourth pattern, rest-rest-attack, was better recognized in the discrete sequence.

Confidence Data

The dependent variable used to estimate confidence was the proportion of time the subject indicated a high rather than a low confidence. Table 4 is a summary of the results of an analysis of variance performed on these data. The analysis did not yield as many significant effects as the analysis of prediction data, but the significant effects which resulted complement those of the analysis of predictions.

Neither the main effect of strength nor that of continuity was significant, indicating that confidence in the correctness of choice was not affected by pattern strength or continuity. As indicated by the significant effect of experience ($p < .001$), confidence increased across periods. This finding is not surprising, since subjects displayed increased skill in pattern prediction across periods.

The main effect of form ($p < .001$) agrees with the prediction analysis in that degree of confidence expressed by subjects reflected the same ordinal relationship as pattern predictions. This relationship may be observed in Table 5 which presents data combined across periods, strengths and continuity levels. The conclusion drawn from these data is that subjects experienced varying amounts of difficulty in mastering each pattern form.

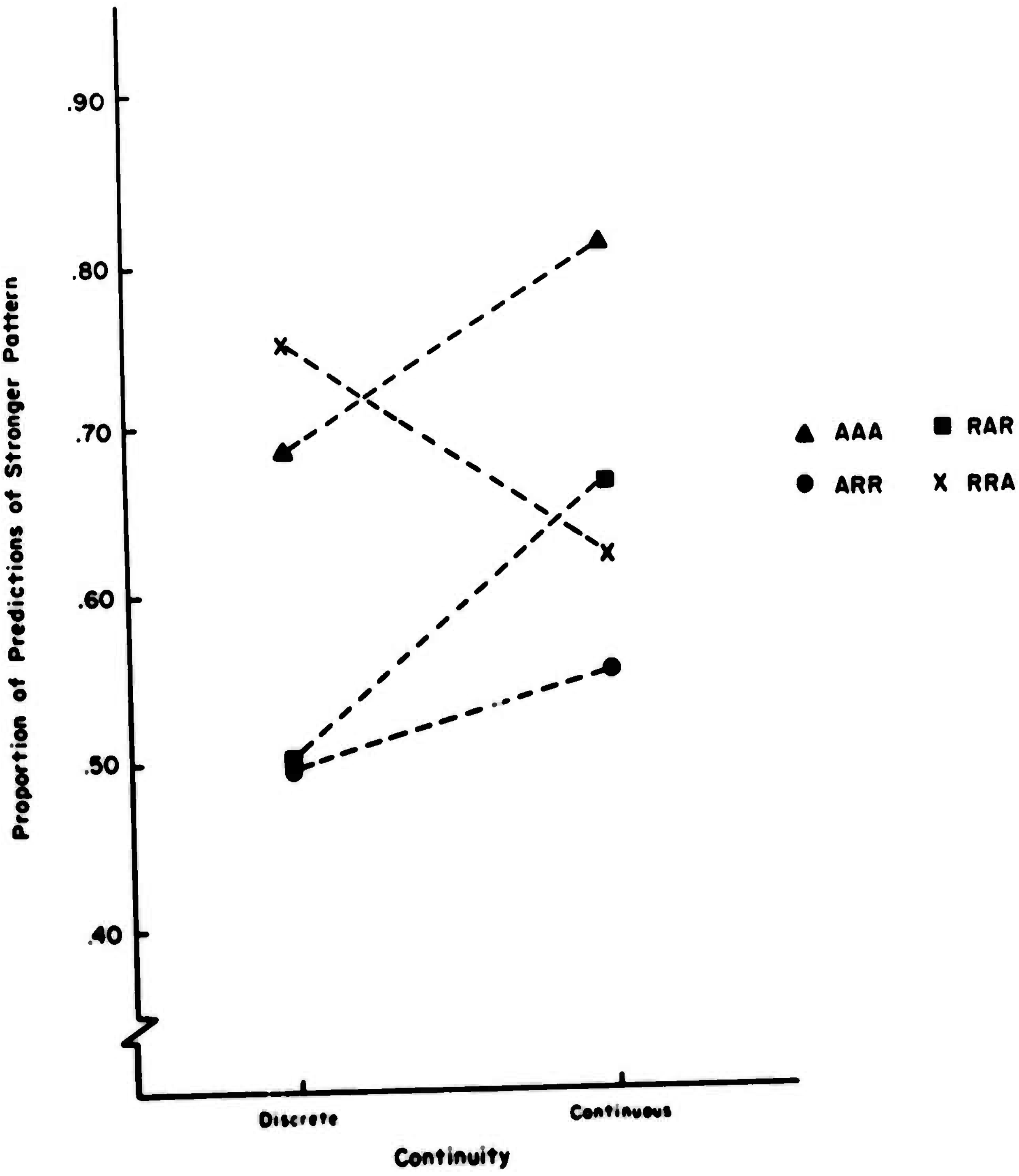

Figure 3 Proportion of predictions of stronger second-order patterns as a function of continuity

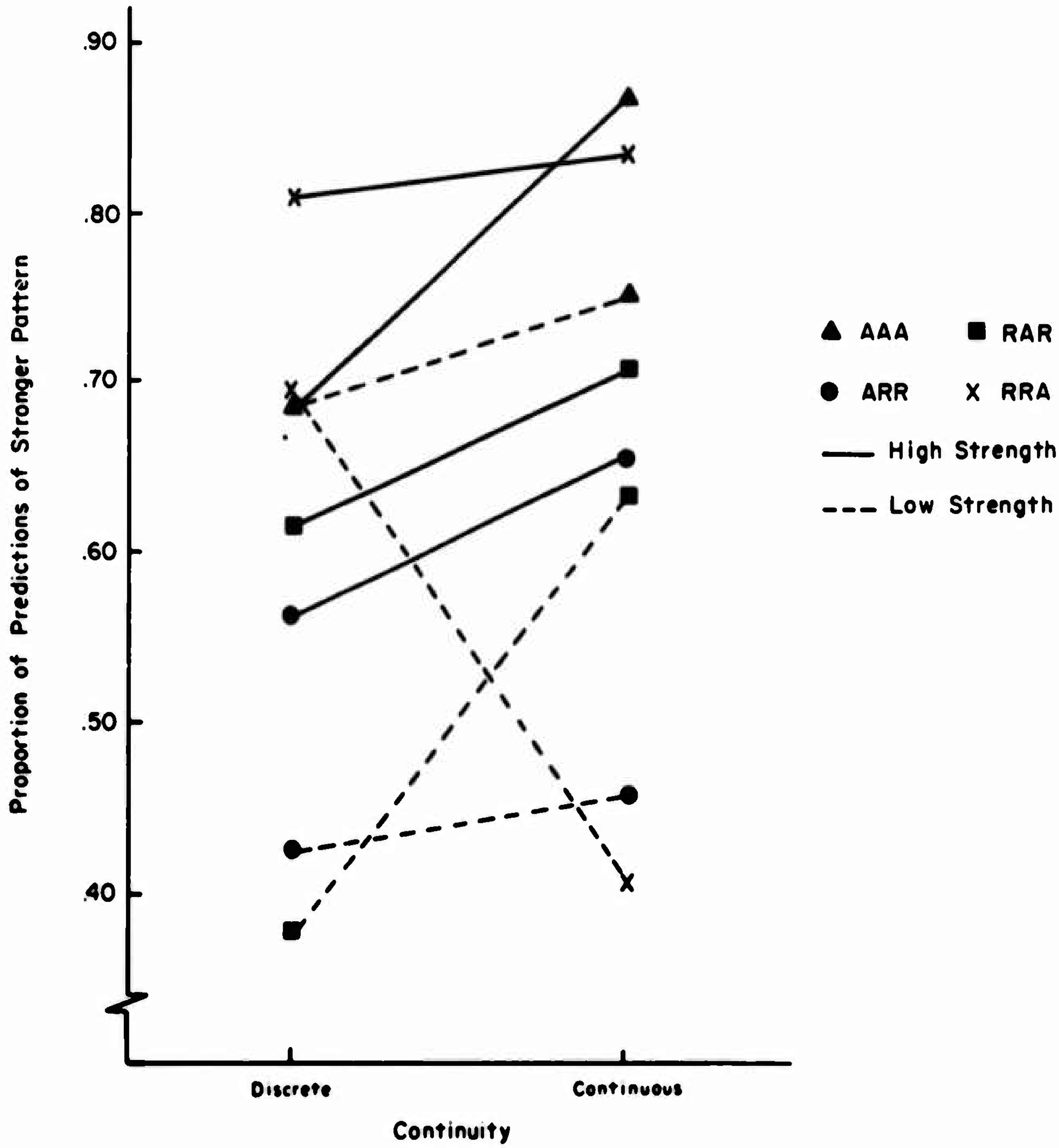

Figure 4 Proportion of predictions of stronger second-order patterns for continuous vs discrete presentation and for each pattern strength

Table 4

ANALYSIS OF VARIANCE SUMMARY TABLE ON CONFIDENCE DATA

Source	df	MS	F	p
Between Subjects	(47)			
Strength (S)	1	117.513		
Continuity (C)	1	555.775		
S x C	1	22.750		
Ssw/SC	44	1116.791		
Within Subjects	(1872)			
Form (F)	3	814.124	7.72	.001
F x S	3	231.178	2.19	.10
F x C	3	258.904	2.46	.10
F x S x C	3	68.935		
F x Ssw/SC	132	105.401		
Experience (E)	9	185.964	6.40	.001
E x S	9	12.919		
E x C	9	19.309		
E x S x C	9	26.203		
E x Ssw/SC	396	29.070		
F x E	27	9.163	1.00	
F x E x S	27	10.596	1.16	
F x E x C	27	9.438	1.03	
F x E x S x C	27	7.807		
F x E x Ssw/SC	1188	9.156		

Table 5

COMPARISON OF AVERAGE PREDICTION AND CONFIDENCE FOR EACH PATTERN FORM

	Pattern Form			
	AAA	ARR	RAR	RRA
Prediction	75%	52%	58%	69%
High Confidence	73%	61%	64%	68%

CONCLUSIONS

The present study provides some insights into the ability of decision makers to perceive patterns in a series of events. A very simple pattern such as repetition of the same event is easily recognized at high and low frequencies of occurrence. More complex patterns require a frequency of occurrence greater than 68% before they will be perceived. Finally, pattern recognition depends a great deal on the amount of continuity in the event sequence. Patterns are better recognized when they occur continuously over time than when they occur in discrete units.

IMPLICATIONS OF FINDINGS

Two implications derive from the present study: Man is capable of learning second-order military event patterns when they occur with a frequency of 80% or higher. Subjects exposed to the high strength patterns initially predicted their occurrence only 60% of the time (Figure 1), but by the conclusion of the experiment were predicting the second-order patterns as frequently as they were occurring, 80%. Thus, if the event patterns are of this strength, complex automated systems are likely to add little to performance in terms of pattern recognition. This implication was also drawn by Howell (9). On the basis of the results of several command and control system simulation experiments, Howell stated that systems which habitually handle predictive data of high strength have little to gain from automating the decision process.

In situations in which the patterns are of low strength, however, computer aids would be quite helpful. The present findings indicate that persons are unable to recognize three of four patterns occurring at 68% strength. Only one pattern, attack-attack-attack, was recognized at this strength level. Thus, subjects were not able to take advantage of a considerable amount of predictability present in the event sequence. It may well be that many enemy activity patterns would occur at a low strength level to capitalize on man's difficulty in recognizing weak patterns. Computers could be programmed to perform many complicated statistical analyses on enemy events and to detect weak but significant patterns in an apparently random set of enemy actions.

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	Office, Chief of Research and Development, Wash., D. C.

As part of the continuing effort to provide research information which will facilitate maximum operations effectiveness within command information processing systems, the TACTICAL OPERATIONS SYSTEM (TOS) Work Unit undertook a study of perception of military event patterns. The focus of the study was the recognition of complex cues to enemy action. Objectives of the investigation, reported in the present publication, were to determine the role of 1) different forms of second-order patterns, 2) second-order pattern strength, 3) continuity, and 4) experience as factors in the recognition of second-order patterns. In the experiment, 48 enlisted men viewed sequences of military events representing eight patterns (form), high and low pattern strength, continuous vs discrete occurrence, and experience (from one to ten 100-trial periods) presented in systematic design on CRT screens. The subjects participated in two experimental sessions, each consisting of five 100-trial periods with 10-minute interval breaks. Each man worked individually and was self-paced. The men indicated which of two enemy activities, A(ttack) or R(est), was likely to follow each two previous events. They also responded to indicate confidence in their decisions. Findings showed that given event patterns occurring with high frequency (80% of the time), the decision maker learned to predict the third sequential event as often as it occurred. However, under conditions of less frequent pattern occurrence (68% or less of the time), pattern recognition did not occur: Only one second-order pattern was predicted as often as it appeared. Confidence in predicted decisions was affected by increase in experience and pattern form but not by pattern strength nor continuity. It appears from the present findings that tentative limits are set on second-order military pattern recognition. Men can perceive strong second-order patterns. Computer aids would be quite helpful, however, in situations where military event patterns of the class investigated are weak but substantial enough to improve decision accuracy.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
*Decision making						
Simulation						
Computer aids						
*Perception						
CRT (Cathode Ray Tube)						
*Sequence patterns						
*Cues						
*Pattern recognition						
Probability learning						
*Pattern (sequence) prediction						
Military psychology						
Event structure						
Military activity patterns						
Statistical analysis						
Information displays						
Tactical Operations Systems (TOS)						